Simulation Meets Reality—Chemical Hazard Models in Real World Use

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ABSTRACT

In 1989 the federal government released a set of models for analysis of chemical hazards on personal computers. The models have been distributed to emergency planners and analysts in government and industry. Argonne National Laboratory conducted workshops in 1990 and 1991 to train these individuals how to use the models. The models have received substantial use in emergency planning and analysis. The experiences of these end users—mostly not simulation specialists—are instructive for other emergency personnel and for simulation specialists who work with them.

INTRODUCTION

In 1989 the U.S. Department of Transportation (DOT), Federal Emergency Management Agency (FEMA), and U.S. Environmental Protection Agency (EPA) released a set of models for analysis of chemical hazards on personal computers. The models, known collectively as ARCHIE (Automated Resource for Chemical Hazard Incident Evaluation), have been distributed free of charge to thousands of emergency planners and analysts in state governments, Local Emergency Planning Committees (LEPCs), and industry. Under DOT and FEMA sponsorship Argonne National Laboratory (ANL) conducted workshops in 1990 and 1991 to train federal, state, local government, and industry personnel, both end users and other trainers, in the use of the models. As a result of these distribution and training efforts ARCHIE has received substantial use by state, local, and industrial emergency management personnel.

THE MODELS

ARCHIE consists of a set of models designed to analyze the effects of releases of toxic, flammable, and explosive materials. ARCHIE is designed to be a fairly detailed and comprehensive analytical tool. Therefore, it requires moderately detailed inputs from users. In addition to basic chemical and physical properties of the material being analyzed the user must enter data about the size and shape of the storage container, physical characteristics of the rupture, and meteorological conditions at the time of release. In return ARCHIE calculates distances and durations of toxic vapor concentrations from gaseous and liquid releases, distances of fire effects from flammable substances, and extent of damage at various distances from explosions. ARCHIE is accompanied by a detailed handbook (FEMA *et al*, 1989) that provides both documentation for use of the models and guidance about the chemistry of hazardous materials and the process of hazards analysis.

The detail that ARCHIE requires in its inputs and that it provides in its outputs suggests certain usages of the models as most appropriate. For preliminary screening of toxic hazards—the first stage of the hazards analysis process as advocated by EPA, DOT, and FEMA—the detail built into ARCHIE is not needed. Other federally sponsored software—notably Computer-Aided Management of Emergency Operations (CAMEO)—is better suited for initial screening of toxic hazards because of its greater ease of input and intentional "rough cut" approach to analysis. But, once potential toxic hazards have been identified through initial screening the more detailed approach of ARCHIE can be used to further refine the analysis for planning purposes. Also, ARCHIE enables the user to analyze flammable and explosive hazards in both initial screening and more detailed planning. At the time of an accident the biggest hindrance to the use of ARCHIE is the time required to assemble and enter detailed input data. Therefore, in real time use ARCHIE is best suited for situations that are not time critical, for example, analysis of slow breaking events or post-event analysis. Also,

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ARCHIE can be used during the planning stage to prepare and store a library of typical event scenarios that can be recalled and modified quickly at the time of an actual incident.

THE WORKSHOPS

In 1990 and 1991 ANL presented several workshops sponsored by DOT and FEMA to train emergency management personnel how to use the ARCHIE models (Early *et al.* 1990a). Audiences for the workshops consisted of federal, state, local government, and industrial personnel. Most participants were potential end users of the models. Some participants attended in order to learn how to pass on the training to others. Many of the participants had little or no prior experience with computers. The objectives of the workshops were to introduce ARCHIE and its documentation, provide guidance on the use of the models, and give the participants hands–on practice in using the models. Some of the workshops were presented in conjunction with EPA–sponsored instruction on the hazards analysis process.

Virtually all of the workshop participants, including those with little computer experience, recognized the potential value of tools like ARCHIE for planning their responses to hazardous materials incidents. The working of several hands–on practice problems convinced participants that ARCHIE was a practical tool to use, but, that it must be used with care to ensure that appropriate input data values are used.

USE OF THE MODELS

ARCHIE has been eagerly received by the emergency management community. Evidence of its use is somewhat anecdotal. But, the experiences of those who have used it are instructive for other emergency planners and analysts and for simulation specialists who work with them. Three case histories follow.

Denver Fire Department

In Regional offices of FEMA, technological hazards staff who were introduced to ARCHIE at ANL's workshops have themselves passed on introductory training to state and local governments in their Regions. A notable example of this transfer of simulation technology occurred in FEMA Region VIII (comprising Colorado, North Dakota, South Dakota, Montana, Utah, and Wyoming). Having been introduced to ARCHIE by FEMA Regional staff the City of Denver Fire Department decided to require analyses using ARCHIE for all tanks of propane in their jurisdiction. To facilitate such analyses by the owners of these tanks ANL was asked by FEMA to provide them with calculations for a few standardized scenarios that could be adapted to specific instances. In consultation with the city fire department FEMA chose three sets of typical weather conditions and two combinations of tank size and rupture size to be analyzed for the standardized scenarios. ANL researched and documented additional input data and assumptions used in the analyses.

The chemical properties of propane required as inputs to ARCHIE were taken from standard chemistry and engineering references (Lewis 1991; Marks *et al.* 1978). The stated values of several properties of propane varied slightly among various chemical reference handbooks, without explanation. Possibly some references reported values under the common of name "propane" for mixtures of hydrocarbons that are commonly called "propane," but are not purely C_3H_8. The variation in these values was not enough to significantly change ARCHIE's calculated results for purposes of emergency planning. But, the variation in values did raise a question from Denver Fire Department personnel when they observed that the input data differed from values reported in their customary chemical reference handbook.

There appears to be a lesson here for the purveyors of simulation to the emergency management community. ARCHIE's standard output report always includes a tabulation of the input data, including the chemical properties entered by the user. However, many models having functions similar to ARCHIE come with a built–in data base of chemical properties. These data may not be evident to the user unless explicitly accessed. One wonders if an end user such as the Denver Fire Department would have questioned the input data were the data contained internally in a data base instead of reported explicitly in the output report. In this case the largest evident variations in the input data had no significant effect. Therefore, one might conclude that no harm would have been done had the input data not been explicitly open to question. However, the occurrence of the question provided an opportunity to further educate these users of ARCHIE about the interpretation of its results. It is our belief that such review and discussion of inputs and outputs between simulation specialists and emergency management end users should be encouraged so that users better understand the significance (or lack thereof) of simulation results. In that way users can be better enabled to make correct inferences from simulation models for emergency management practice.

In this case the end users of ARCHIE—the city fire department—did not themselves have to operate the ARCHIE models. But, they did have to understand the value and results of the models for planning purposes. From their questions it became apparent that the fire department was scrutinizing the analyses, not simply filing them for reference or passing them on unexamined to tank owners. In this case the variations in data were slight enough to make no practical difference. But, the raising of the question points up the care with which the results of such analyses must be presented to and by end users. The ARCHIE handbook (FEMA *et al*, 1989) points out that many modelers consider dispersion models to be in good agreement if their results differ by no more than a factor of two (!). Similar statements, though perhaps differing quantitatively, could be made about the fire and explosion models in ARCHIE. But, in addition to such statements in the official documentation it can hardly be overemphasized, even when said on each occasion that model results are presented, that for emergency planning purposes an effect distance estimated to be, for instance, 1637 ft in one scenario or by one model is not really different from an estimate of 1721 ft produced by a slightly different scenario or model.

State of Ohio

In the State of Ohio Emergency Operations Center (EOC) the hazard assessment group uses several computer models, including ARCHIE, to analyze hazardous materials spills and provide advice on protective actions to affected local governments. One of the training workshops presented by ANL was given in 1990 at the State of Ohio EOC and attended by many state emergency management personnel. In a 1991 hazardous materials exercise involving three states and many counties the State of Ohio used ARCHIE to evaluate a hypothetical spill of benzene into the Ohio River. The timing of events in this exercise was such that counties bordering the river needed to make and implement protective action decisions immediately, and so, could not wait for advice from the state. But, the state's advice was used to confirm the protective actions already underway, to extend those actions as a precaution farther along the river and to greater distances from the river, and to estimate the required duration of those actions before the chemicals would dissipate.

In this case the users of ARCHIE were well informed about the use of such models and were completely conversant with the input data required by ARCHIE. They were able to use the models effectively in a strategic capacity. However, these users were hampered by ARCHIE's user interface, which in version 1.0 requires the input of specific data in specific forms that do not always match the forms in which these data are listed in reference handbooks held by the users. The users had to perform hand calculations to convert data from the forms given in their handbooks to the forms required by ARCHIE. The resulting delay lessened the effectiveness of the use of ARCHIE to provide timely protective action guidance.

The difficulties encountered by the State of Ohio suggest two possible solutions. First, observers of the exercise suggested to state personnel that they prepare a library of standardized ARCHIE scenarios for those chemicals that are commonly produced or transported along the state's waterways. Then at the time of an incident only the data specific to that incident, such as weather conditions and spill size, would need to be changed. State personnel were receptive to this suggestion. But, this case also points up the need for simulation programmers to provide maximum flexibility to the user in defining input data for emergency management models. Input data should be defined in terms with which the users are familiar. And, where data are commonly used in several alternative forms (for example, size of a tank measured by linear dimensions or by volume, in English or metric units) all such forms should be available to the users as options.

Dialog between industry and LEPCs

ARCHIE has been used by consultants to the chemical industry to help emergency management personnel in industry and in LEPCs address questions of the geographic scope of emergency planning (Early *et al*. 1990b; Newsom 1991a; Newsom 1991b). In one case an LEPC had conducted an initial screening for a chemical manufacturing plant, estimating a large vulnerable zone around the plant. But, both the LEPC and manufacturer had access to ARCHIE. Agreeing to use the same model the LEPC and manufacturer could focus their dialog on identifying more appropriate input data than the initial screening assumptions. Using ARCHIE with more detailed input data the LEPC and manufacturer were able to agree on a smaller estimated vulnerable zone, to both parties' benefit.

In another case an industrial user of a hazardous chemical contended that they did not store enough of a chemical on-site to create a public hazard outside the plant boundary. Using ARCHIE a consultant was able to show management that plausible accident conditions could result in concentrations of chemical vapor that would be harmful to people living near the plant. Shown these results management was convinced to reduce the inventory of the chemical stored on-site.

These examples illustrate one of the values of simulation in emergency management. Where agreement can be reached on the validity of a simulation tool, that tool can form the basis for dialog that focuses on substantive issues. Dialog can address assumptions made by the parties and the consequences of those assumptions for public safety. This process works best when the parties use a mutually agreeable model. The process may still work when different parties use different models. But, in that case it will be especially crucial for knowledgeable simulation specialists to help the model users correctly interpret the results of the models, so as to identify when nominal differences in results are or are not significant.

CONCLUSIONS

These case histories point to several lessons for the emergency management community and for simulation specialists. The cases show clearly that simulation has a significant contribution to make to emergency planning and analysis. Further, it is apparent that with readily available software emergency personnel can be end users of simulation technology, not just clients for professional simulation specialists. The Denver experience indicates that it is beneficial to have simulation data—both input and output—open to review and question by the end user. Simulation specialists—trainers and consultants—must emphasize to end users the correct interpretation of the data. The Ohio experience illustrates the need for model developers to design flexible user interfaces that accommodate the ways that emergency personnel think and work.

REFERENCES

Early, W.F., M.C. Livingston and D.E. Newsom. 1990a. "A Pilot Program for Introduction of ARCHIE (Automated Resource for Chemical Hazard Incident Evaluation)." In *Proceedings of the 1990 Hazardous Material Spills Conference* (Houston, TX, May 13-17). AIChE, New York, NY.

Early, W.F., M.C. Livingston and D.E. Newsom. 1990b. "ARCHIE Evaluates Hazardous Incidents." *Hydrocarbon Processing* 69, no. 11 (Nov.): 69-73.

Federal Emergency Management Agency, U.S. Department of Transportation and U.S. Environmental Protection Agency. 1989. *Handbook of Chemical Hazard Analysis Procedures*. U.S. Government Printing Office, Washington, DC.

Lewis, R.J. 1991. *Hazardous Chemicals Desk Reference*, 2nd ed. Van Nostrand Reinhold, New York, NY.

Marks, L.S., T. Baumeister and E. A. Avallone. 1978. *Marks' Standard Handbook for Mechanical Engineers*, 8th ed. McGraw-Hill, New York, NY.

Newsom, D.E. 1991a. "ARCHIE—A Tool for Industry/LEPC Dialog." In *Proceedings of the Fourth Annual Hazardous Materials Management Conference/Central* (Rosemont, IL, Apr. 3-5). Tower Conference Management Company, Glen Ellyn, IL, 909-916.

Newsom, D.E. 1991b. "ARCHIE Promotes Dialogue Between Industry, LEPCs." *Hazmat World* 4, no. 7 (July): 53-57.

BIOGRAPHY

Dr. Donald E. Newsom is an Emergency Systems Engineer at Argonne National Laboratory. Dr. Newsom holds a B.S. in Engineering Sciences, an M.S. in Engineering, and a Ph.D. from Purdue University. He is a registered Professional Engineer in the State of Illinois. He has been a principal figure in training emergency management personnel in the use of computer software in local workshops and in short courses at FEMA's Emergency Management Institute. Off the job he enjoys using computer technology to create electronic music. Dr. Newsom is a member of the Society for Computer Simulation, the Society for Risk Analysis, and the Professional Communication Society of the Institute of Electrical and Electronics Engineers.

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